

Gulf of Mexico Dead Zone—The Last 150 Years

The Problem

A dead zone forms seasonally in the northern Gulf of Mexico when subsurface waters become depleted in dissolved oxygen and cannot support most life (fig. 1). The zone forms west of the Mississippi Delta over the continental shelf off Louisiana and sometimes extends off Texas. The oxygen depletion begins in late spring, increases in summer, and ends in the fall.

The formation of oxygen-depleted subsurface waters has been associated with nutrient-rich discharge from the Mississippi and Atchafalaya Rivers. Bio-available nutrients in the discharge can stimulate algal blooms, which die and are eaten by bacteria, depleting the oxygen in the subsurface water.

The oxygen content of surface waters of normal salinity in the summer is typically more than 8 milligrams per liter (8 mg/L); when oxygen concentrations are less than 2 mg/L, the water is defined as hypoxic (CENR, 2000). The hypoxia kills many organisms that cannot escape, and thus the hypoxic zone is informally known as the “dead zone.”

Shelf-wide surveys of the oxygen content of subsurface waters off Louisiana have been conducted annually in mid-summer since 1985. These surveys demonstrate that the frequency and extent of hypoxia have increased since 1985 (fig. 2; Rabalais and others, 1999). In 2002, the hypoxic zone off Louisiana had a maximum extent of more than 20,000 square kilometers (fig. 2) and was about the size of New Jersey.

The hypoxic zone in the northern Gulf of Mexico is in the center of a productive and valuable fishery. The increased frequency and expansion of hypoxic zones have become an important economic and environmental issue to commercial and recreational users of the fishery.

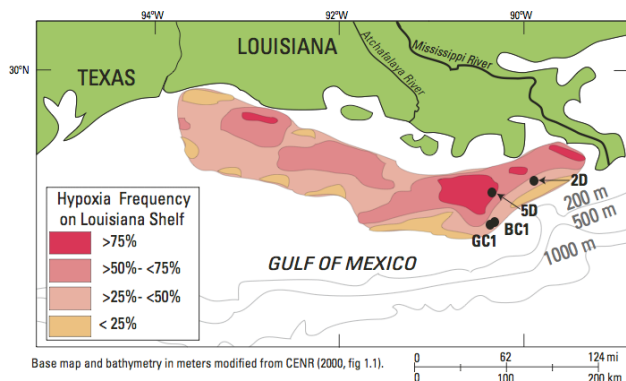


Figure 1. Location and frequency of hypoxia on the Louisiana continental shelf mapped on the basis of measurements made between 1985 and 1999 by N.N. Rabalais (CENR, 2000). The hypoxic zone, also called the dead zone, varies in size and shape and duration; hypoxia is defined as oxygen concentrations in subsurface water of less than 2 milligrams per liter. The four colors show areas that were hypoxic for different percentages of the time. The continental shelf is the area between the shoreline and a water depth of 200 meters (m). Black dots indicate collection localities for the four cores that yielded the foraminifer data plotted in figure 4.

Low-Oxygen Faunal Proxy

To identify long-term trends in oxygen content for periods when systematic measurements were not made, researchers need an indicator, or proxy. U.S. Geological Survey (USGS) scientists and colleagues are working to extend the observational record of oxygen-depleted bottom-water conditions back through time and space by analyzing sediment cores from the Louisiana shelf (fig. 1).

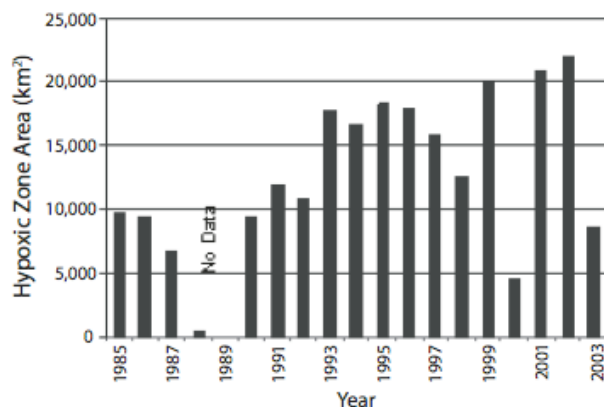


Figure 2. Changes in area of the hypoxic zone on the Louisiana continental shelf from 1985 through 2003, plotted on the basis of measurements made by N.N. Rabalais (Louisiana Universities Marine Consortium, written commun., 2005).

Scientists have found that the abundance of three species of benthic foraminifers, single-celled organisms, in modern and buried sediment samples can indicate low-oxygen events in the water overlying the sea floor where they lived. The three species are *Pseudonion atlanticum*, *Epistominella vitrea*, and *Buliminella morgani*, and their combined abundance is called the PEB index (Osterman and others, 2005). The PEB species live on the surface of the sea floor, are opportunists that prefer nutrient-rich environments, and are tolerant of low-oxygen conditions. The PEB index is much higher in sea-floor samples collected in the Louisiana hypoxic zone than it is in other areas of the Louisiana and Texas shelf. By studying sediment cores recovered from the Louisiana shelf (fig. 3), researchers can reconstruct a history of the PEB index at different sites through time.

The Last 150 Years

The PEB index in four sediment cores is shown in figure 4. The dates for sediment samples are based on a technique using radioactive decay of lead-210 (^{210}Pb). All four cores show a similar stratigraphic pattern of generally increasing PEB values from 1950 to the present (fig. 4). The cores were collected from mean water depths of 24 to 47 meters and encompass an area of about 2,500 square kilometers. Thus, the PEB data indicate that low-oxygen bottom-water conditions have increased since 1950 over the sampled part of the shelf. The trend toward higher PEB values over the last 50 years is consistent with results of previous

studies that have linked the increased occurrence of hypoxia on the Louisiana shelf with higher nutrient loading associated with the use of commercial fertilizer in the Mississippi River Basin (Nelsen and others, 1994).

Several brief excursions to higher values of the PEB index at about 1880, 1900, and 1920 indicate that low-oxygen bottom-water events or intervals occurred in the late 1800s and early 1900s (fig. 4, peaks C–E). The maximum values of the pre-1950 excursions in the PEB index are less than the maximum post-1950 PEB values observed near the top of each core, but several of the excursions are present in more than one core, which indicates that they are reliable events.

Fluctuations in the PEB index prior to 1950 have been attributed to natural variations in Mississippi River discharge that enhanced transport of nutrients and freshwater to nearshore waters (Osterman and others, 2005). A combination of natural processes, as well as possible human activities such as land clearing, may have resulted in the development of widespread algal blooms and associated low-oxygen bottom water on the Louisiana shelf prior to 1950 (Turner and Rabalais, 2003). The results from the four cores studied (fig. 4) indicate that the low-oxygen events of the last few decades were more extreme than any that occurred in the previous 150 years.



Figure 3. USGS scientists describe and sample a sediment core that had been recovered from the Louisiana shelf. The benthic foraminifers from the core are studied for indications of low-oxygen events in the water overlying the sea floor when they were alive. The age of the samples in the core is determined by measuring the decay of radioactive lead-210 (^{210}Pb) in the sediments. Photograph by Marci Marot, U.S. Geological Survey, 2005.

Future Research

The existing record indicates that the development of low-oxygen bottom-water conditions over the last several centuries was a complicated process. Research is underway to understand better how hypoxic zones form and to extend the record of low-oxygen events on the Louisiana shelf in time and space.

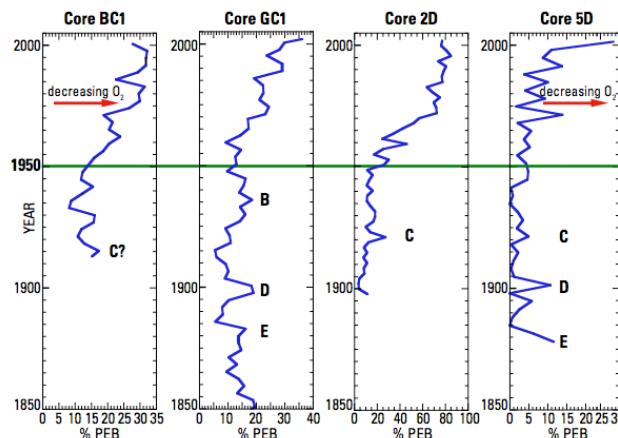


Figure 4. Plots of the PEB index (% PEB) in four sediment cores from the Louisiana shelf (scales vary depending on the maximum percentage of PEB foraminifers). Higher values of the PEB index indicate lower dissolved oxygen (O_2) contents in bottom waters. Years from 1850 to 2003 were derived from measuring the decay of radioactive lead-210 in the sediments. Letters B, C, D, and E label peaks in the PEB index before 1950. All cores show an increasing trend of low-oxygen bottom waters during the last 50 years, and the low-oxygen events of the last few decades are more extreme than any of the pre-1950 events. Locations where cores were collected are shown in figure 1.

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